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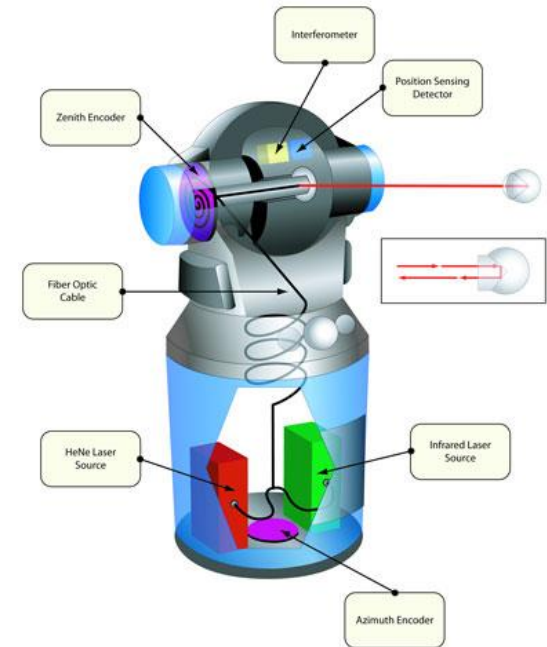
Laser Tracker Position Optimization

Zheng Wang, Alistair Forbes, Paul Maropoulos

DET 2014, Stuttgart

Laser Tracker

- Portable large volume coordinate measuring instrument
- Range 30-50m
- Accuracy 20-200 μ m

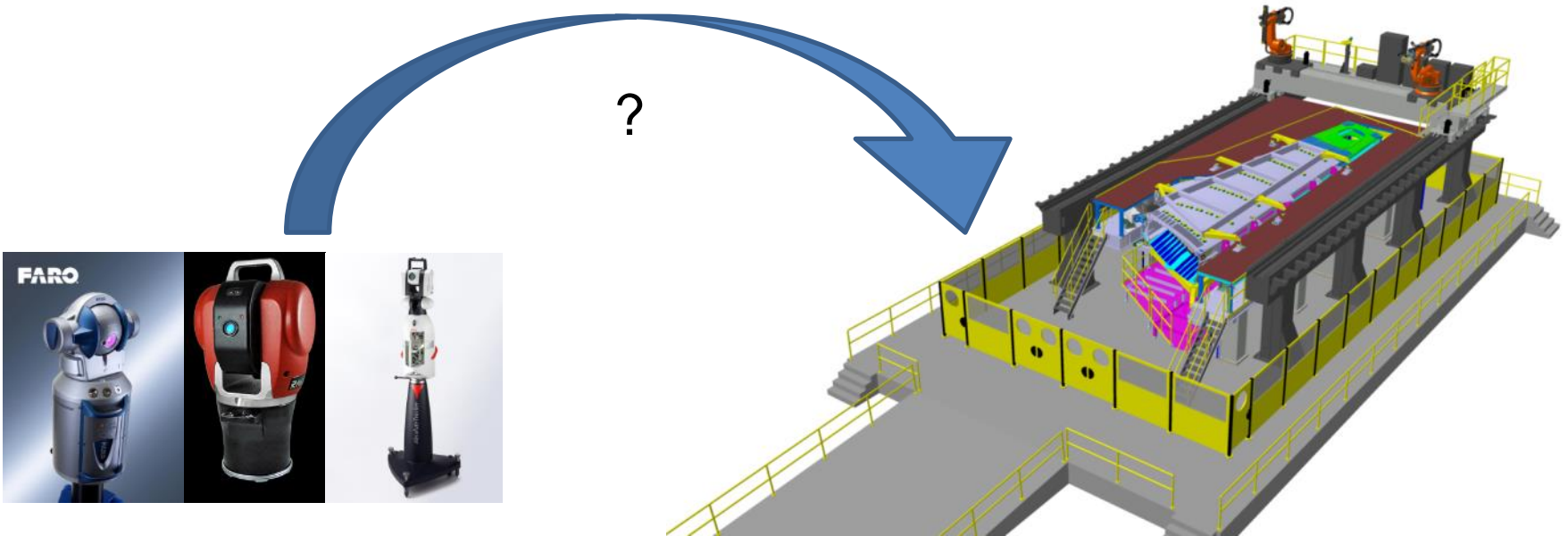


FARO Laser Tracker



The Problem

- Where should I place my tracker/tracker stations?

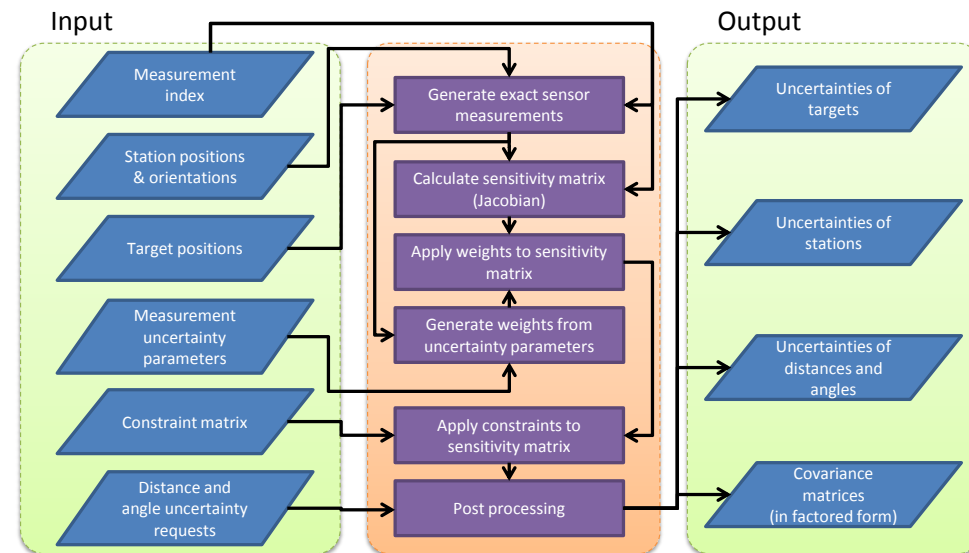


Overview of features

- Based on NPL (Alistair Forbes) multi-station tracker code
- Pattern search, GA, PSO, or hybrid optimization
- Features:
 - 1 – N trackers
 - 1 – N targets (must be > 3 for > 2 trackers)
 - Objective function weighting for points, distances and angles
 - Constraints for tracker positions
 - Constraint for minimum measurement distance
 - GPU accelerated Line-of-sight check with CAD

The NPL Laser Tracker Model

- Specialized version of the NPL generic model
- Inputs:
 - Measurement Index
 - Target & station positions
 - Tracker uncertainty parameters
 - Constraint matrix
 - Distance and angle requests
- Outputs:
 - Uncertainty of targets and stations
 - Covariance matrix
 - Uncertainty of distances and angles

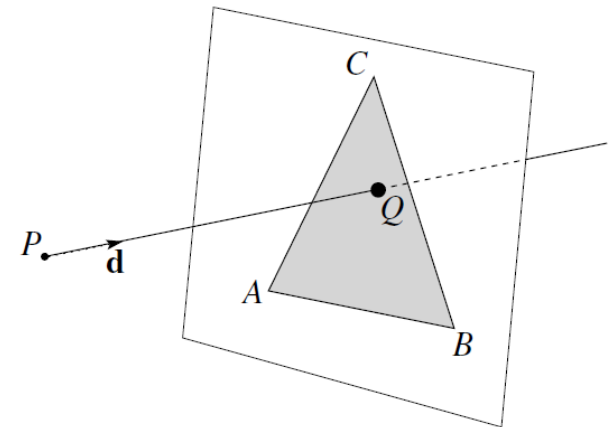
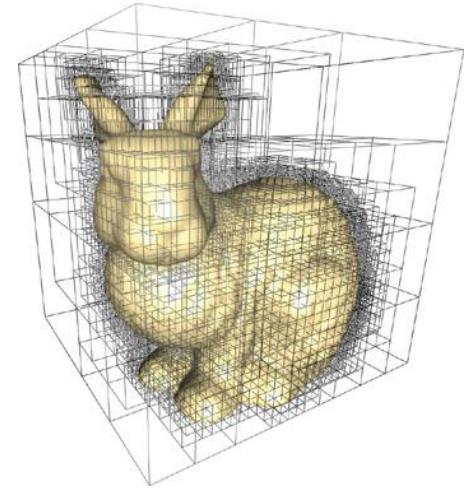


8 Parameter tracker model

$\sigma_{D,A}, \sigma_{D,R}, \sigma_{A,A}, \sigma_{A,R}, \sigma_{E,A}, \sigma_{E,R}, \sigma_L, \sigma_M$

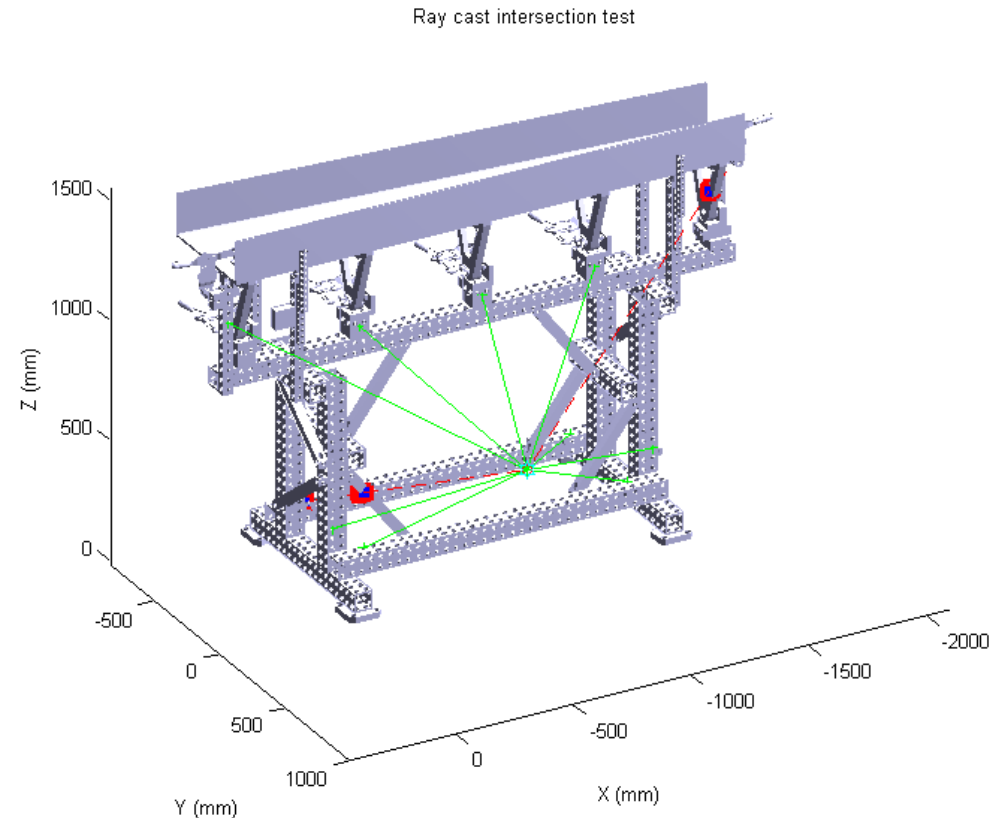
Line-of-sight checking

- Efficient Octree collision detection
- intersection test
- Direct import of .stl files exported from CAD (Catia, etc.)



Line-of-sight checking

- Efficient Octree collision detection
- Direct import of .stl files exported from CAD (Catia, etc.)

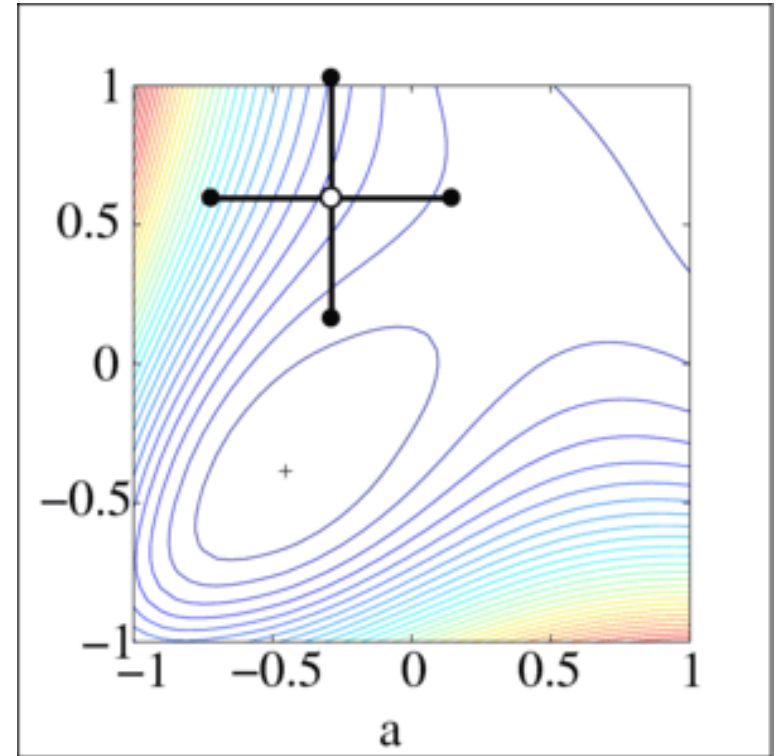


Optimization: Problem Formulation

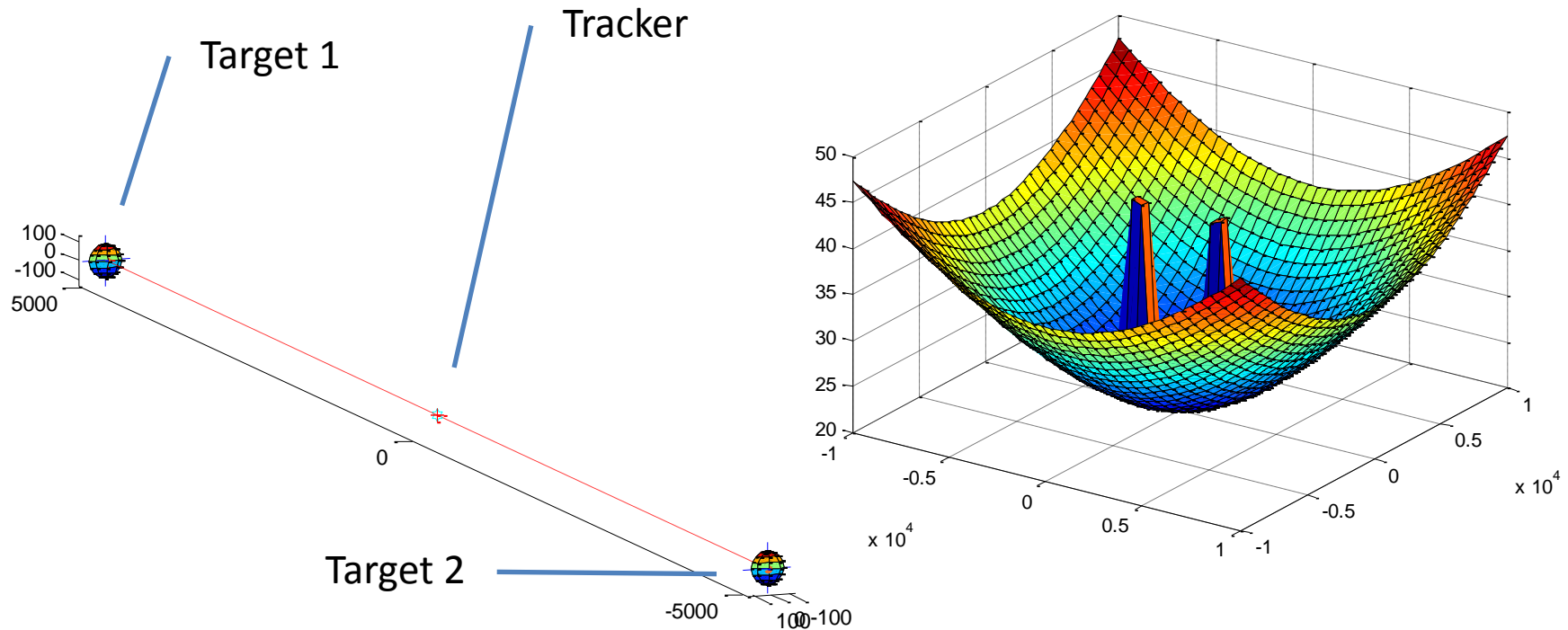
- Objective: minimize either
 - Sum of total of target uncertainties
 - Uncertainties of selected targets, distances and angles
 - Or a weighted sum of the above
- Subjected to:
 - Line of sight constraints
 - Minimum measurement distance constraints
 - Tracker or tracker station position bounds
- By varying:
 - Tracker or tracker station positions

Optimization: Pattern Search

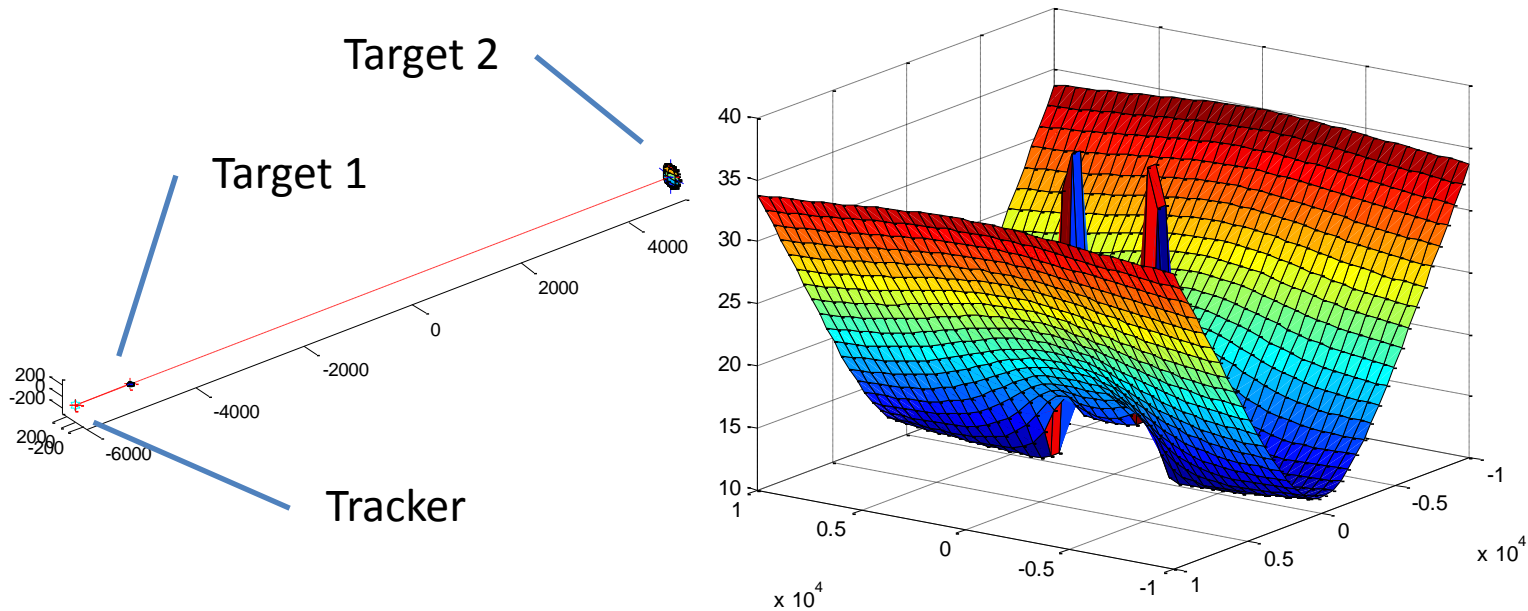
- The objective function is first evaluated at the starting position
- Positions in the cardinal directions are also evaluated
- Re-centre pattern on lowest value, expand pattern size
- If current position is lowest, contract size
- Stop when pattern size is below limit



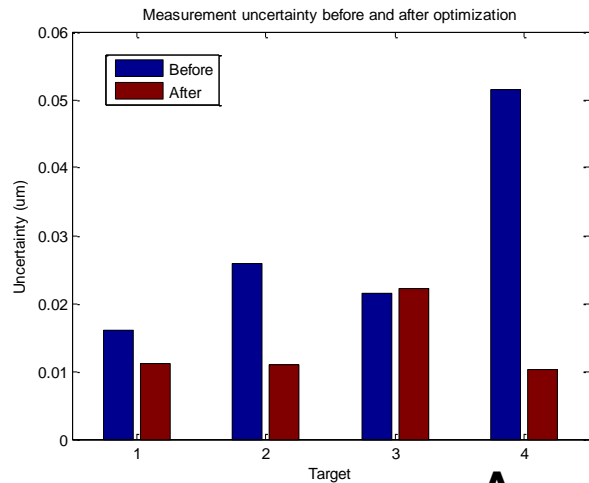
Example Solution for 1 LT 2 Targets



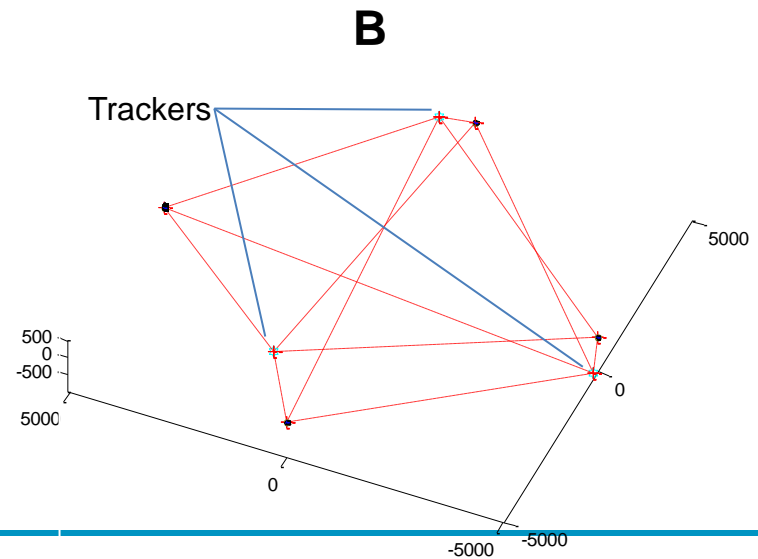
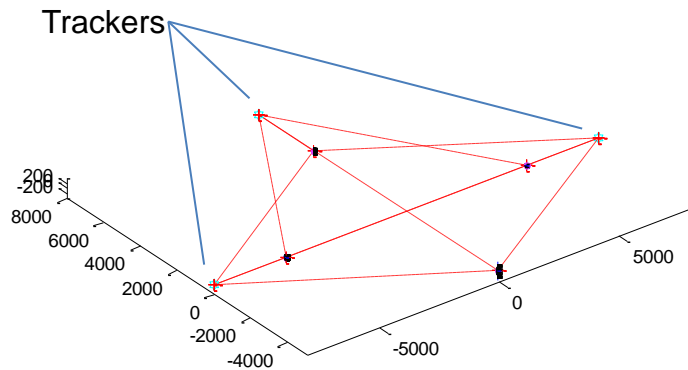
Solution for 1 LT 2 Targets



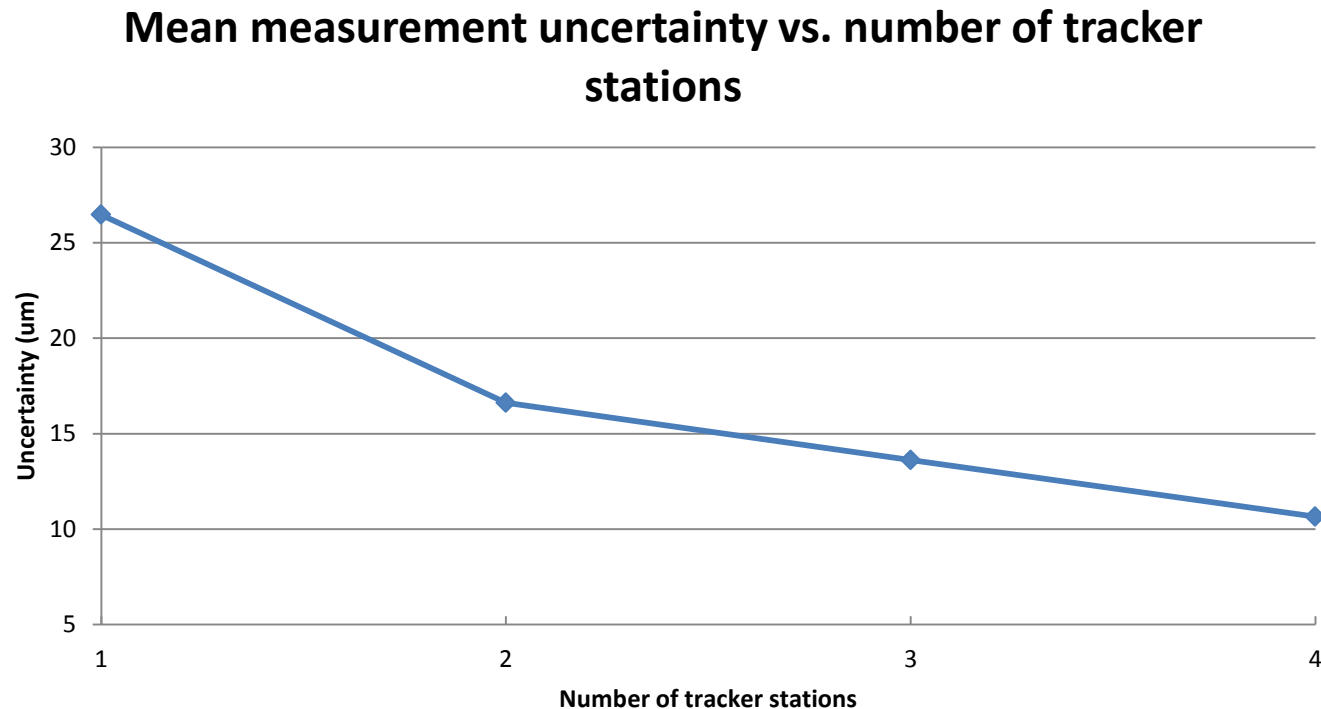
Example Solution 3 LT 4 Targets



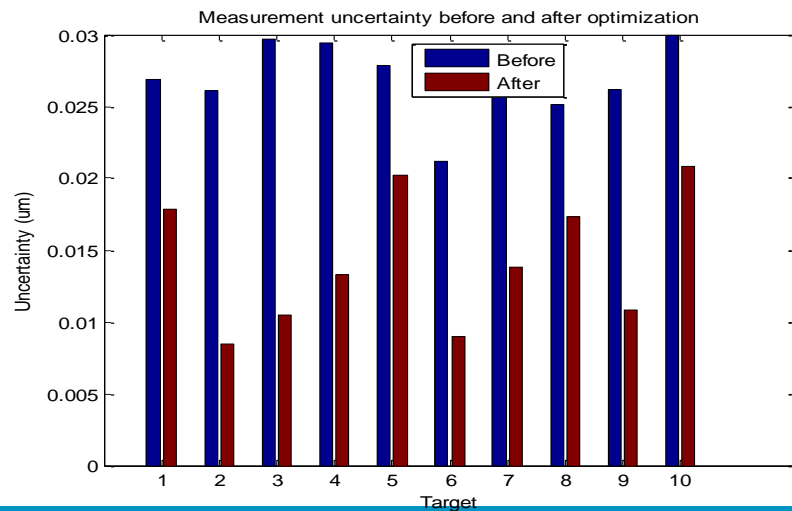
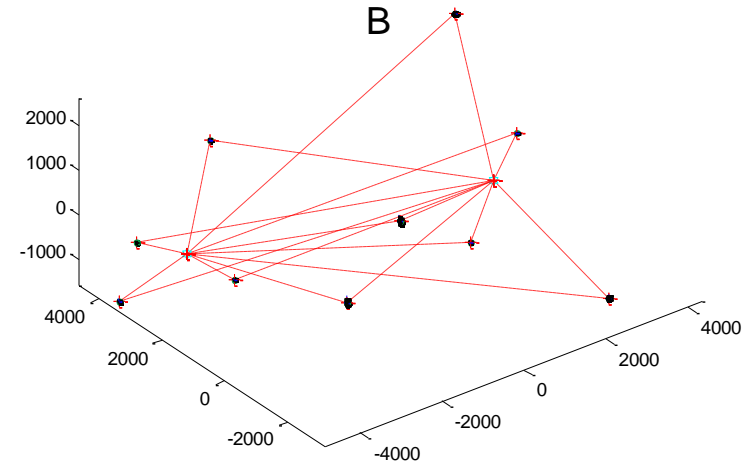
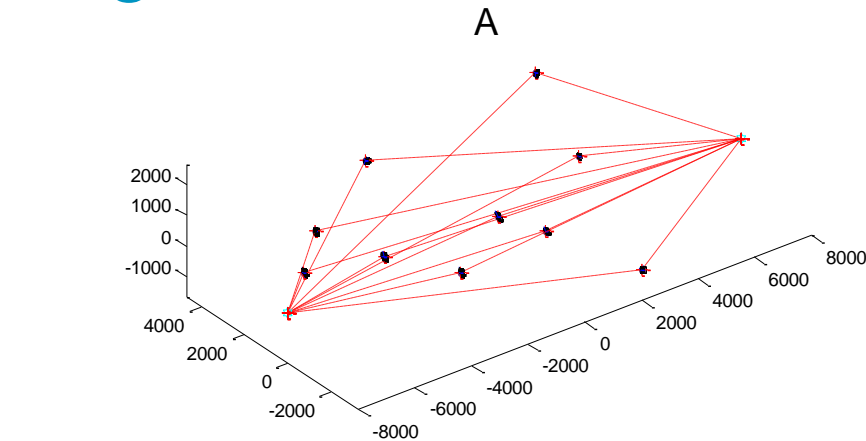
- Vertical position diversity
- Before: 30μm
- After: <15μm



How many tracker stations do I need?

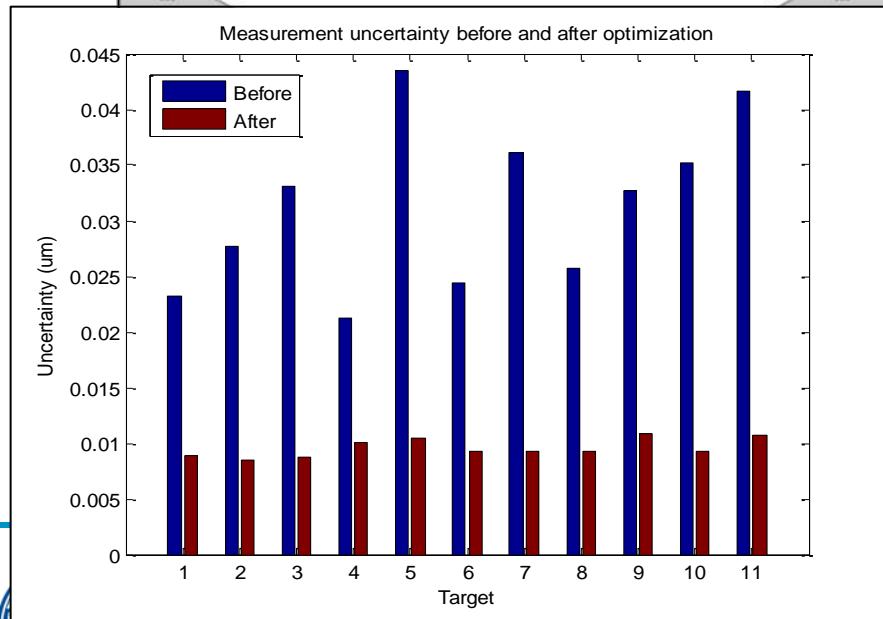
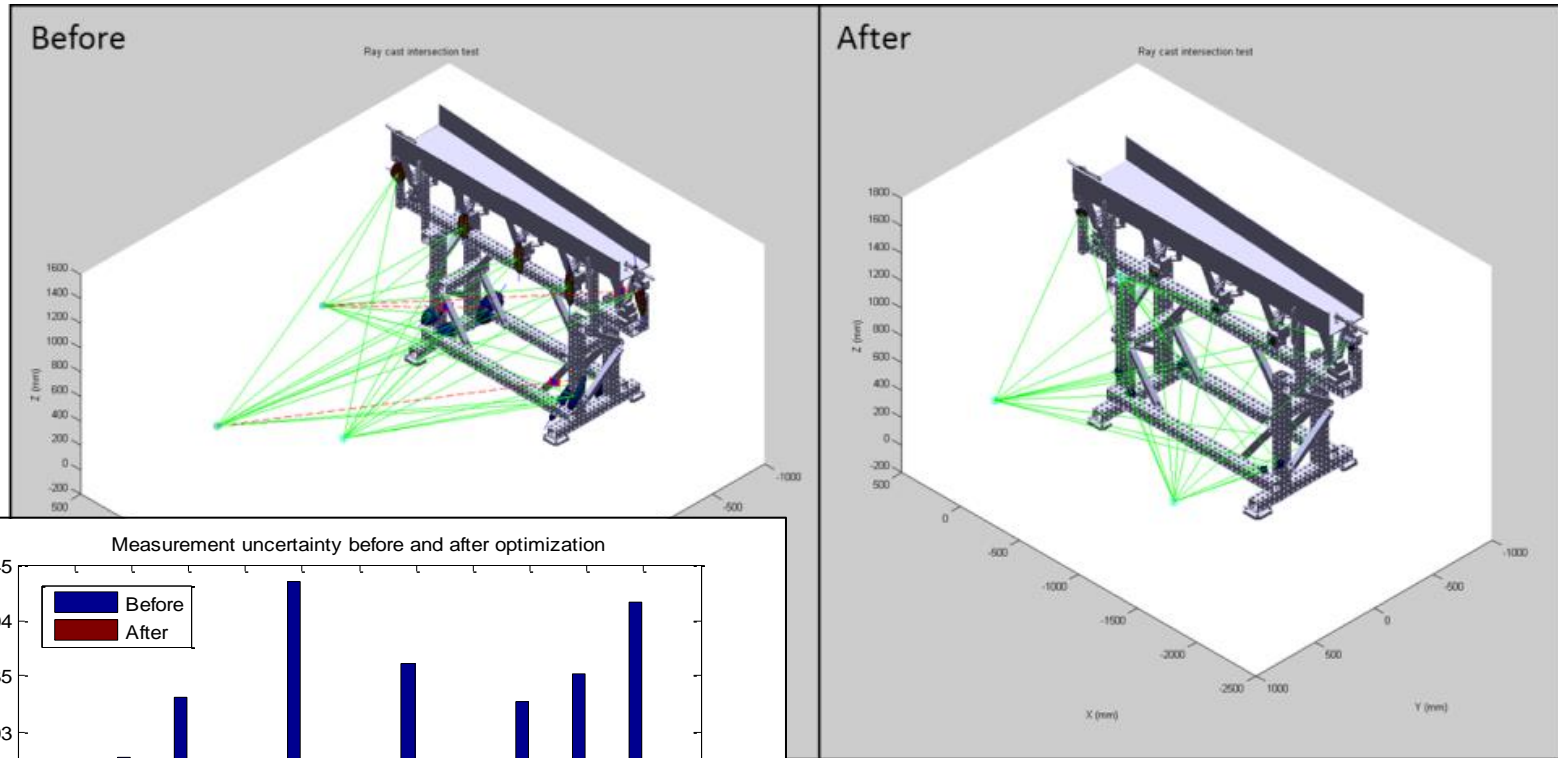


Example Solution for 2 LT 10 Arbitrary Targets



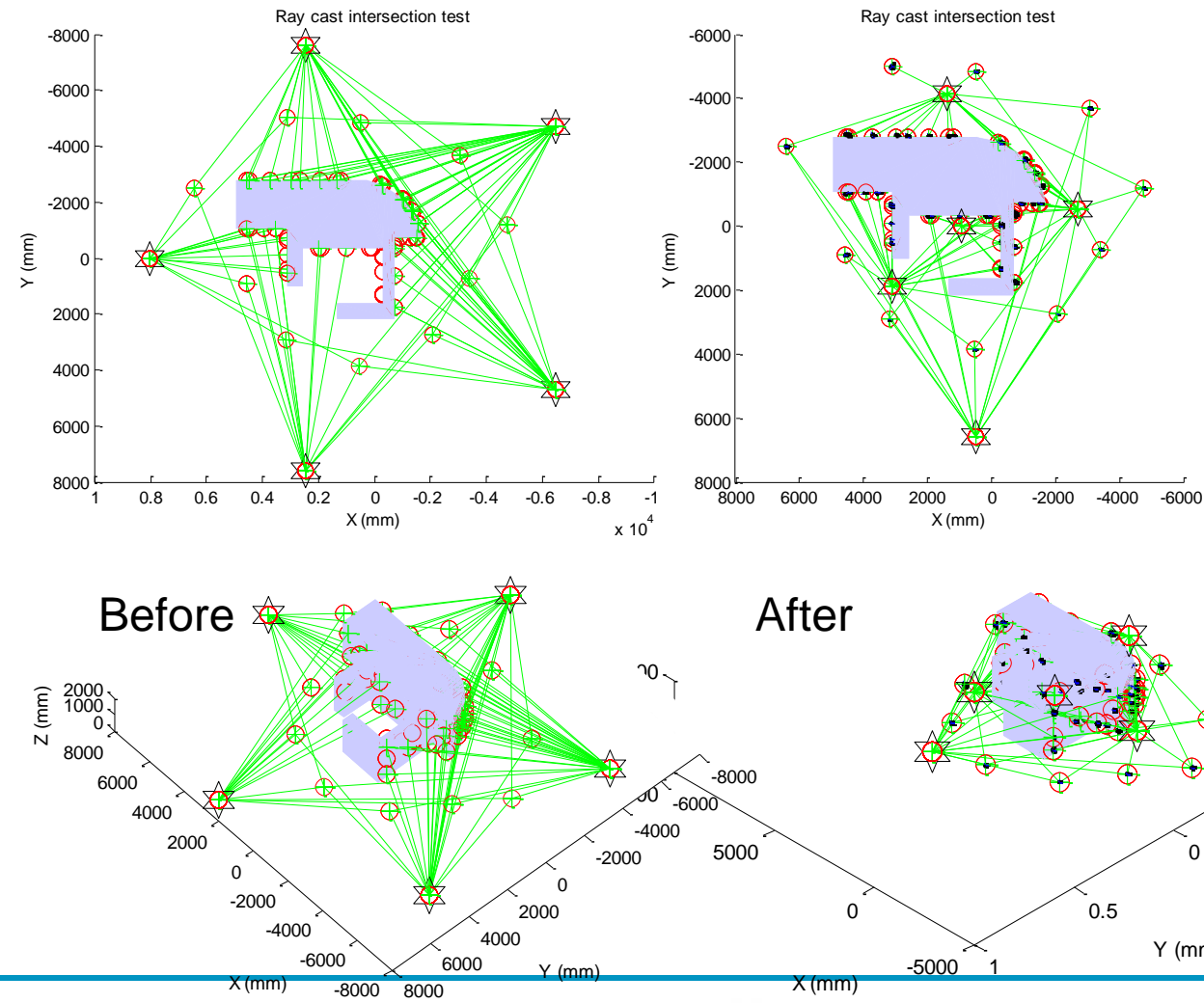
- Tracker closer to targets
- Ray angles close to 90 degrees

Example Solution 3 LT 11 Targets, LOS

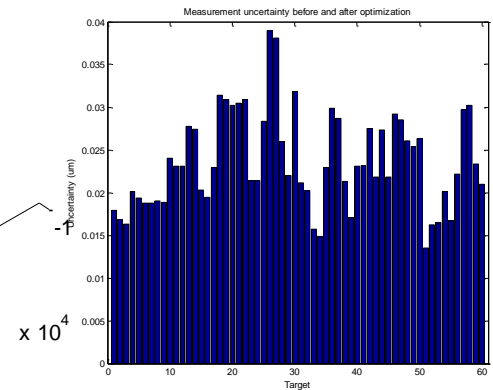


- 59 iterations
- Computation time: 4 min 30 s
- Before: 32.5μm
- After: 8.4μm

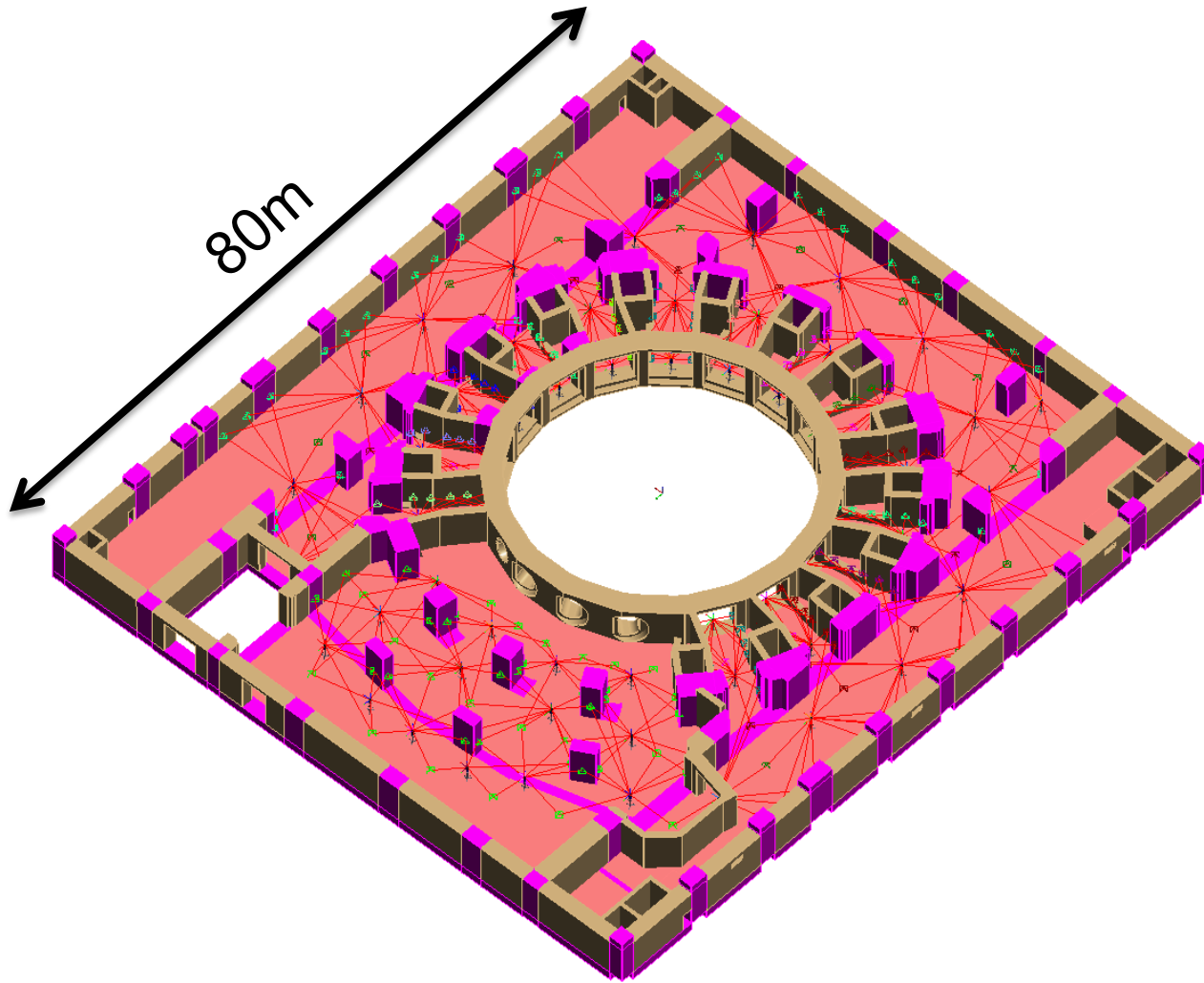
Example Solution 5 LT 60 Targets, LOS



- GA initial search
- 56 iterations
- Computation time: 45 min
- Before: 8 targets missing
- After: all targets measured, 25.1 μ m



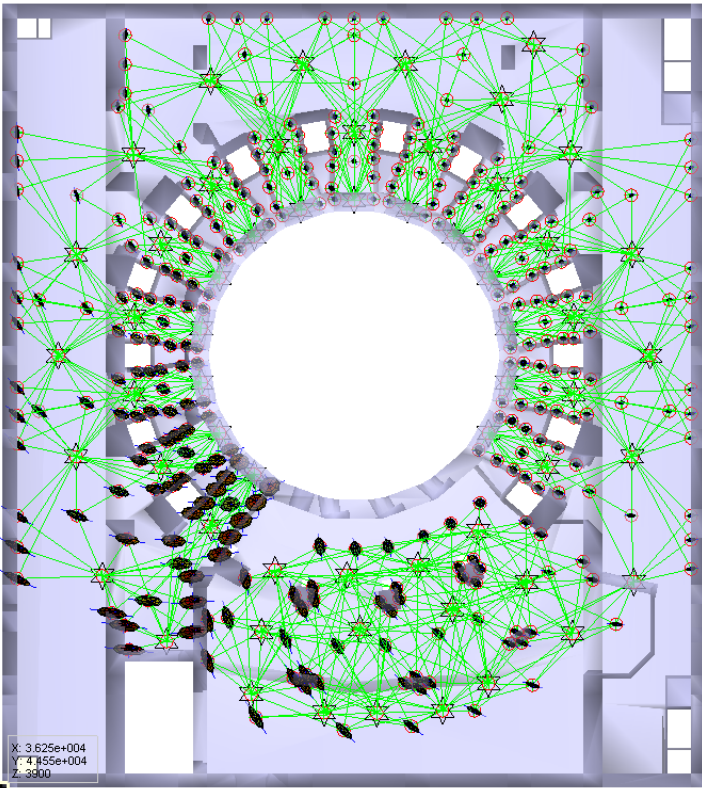
Example Solution: ITER Gallery



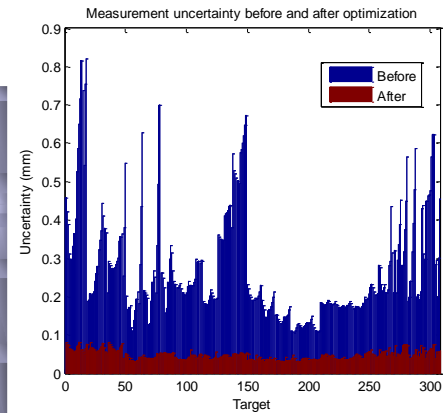
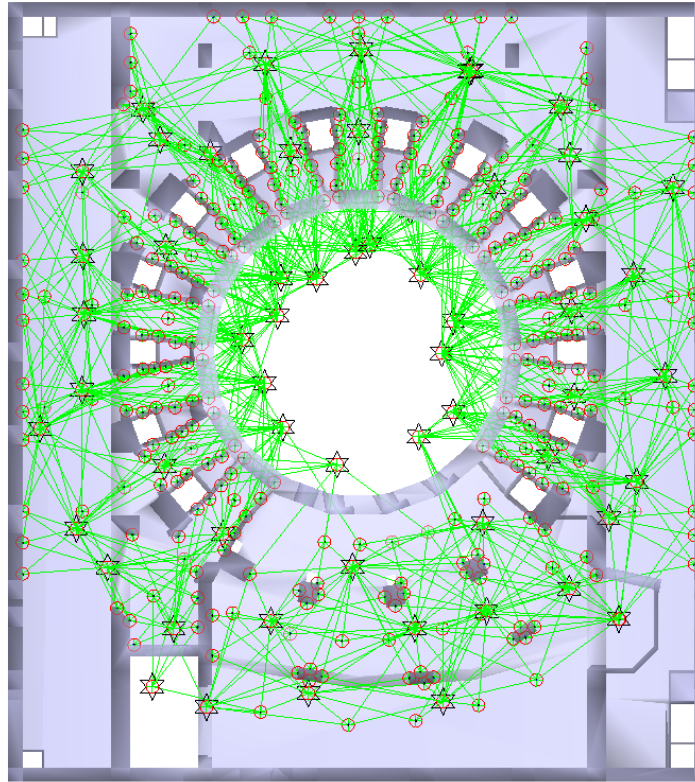
- 58 Trackers
- 308 Targets
- Courtesy of David Wilson (ITER)

Example Solution: ITER Gallery

Before

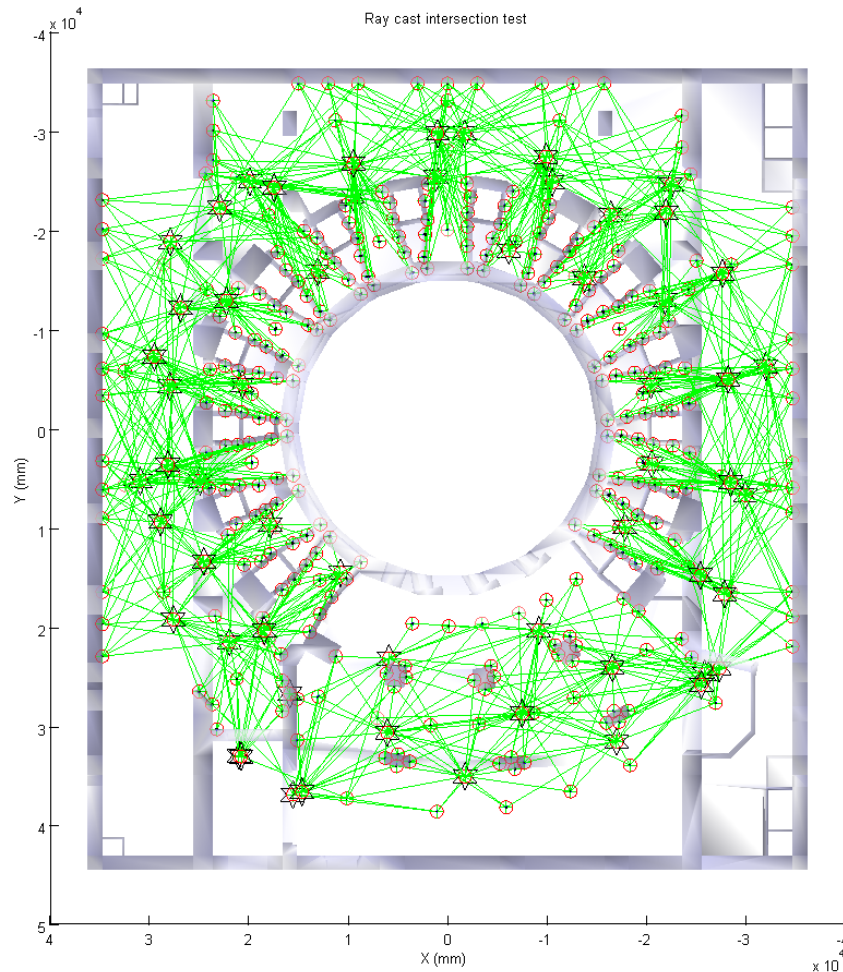


After



- GA initial search
- Computation time: 3 Days
- Before: 273 μ m
- After: 48 μ m

Example Solution: ITER Gallery



With central pit constraint:

- Before: 273 μ m
- After: 55 μ m

Summery

- Laser tracker position optimization code based on the NPL laser tracker model
 - Laser tracker model
 - Line-of-Sight Check
 - Optimization
- Optimized networks can very significantly reduce measurement uncertainties
 - Use cheaper and less accurate instruments
 - Reduce measurement stations and time
 - Plan complex measurements

Future Work

- Improve user interface
- Increase performance
- Industrial case study
- Benchmark against SA
- Use 3D scan instead of CAD
- Extend model
 - Theodolites
 - Laser radar
 - iGPS
 - Multilateration
 - Photogrammetry

